Weatherwise

Dr. Charles F. Brooks

Vol. 7, No. 3
JUNE 1954

"SOME PEOPLE ARE WEATHERWISE BUT MOST ARE OTHERWISE"—BENJAMIN FRANKLIN

WEATHERWISE

THE MAGAZINE ABOUT WEATHER

DAVID M. LUDLUM, *Editor* HENRY W. BULKLEY, *Associate Editor*

Dr. Brooks "Retires"...

THE American Meteorological Society was founded in 1919 largely through the personal energy and enthusiasm of Dr. Charles F. Brooks. He was elected Secretary of the Society at the first meeting and has served ever since. Now after 35 years of complete devotion to the Society, to the profession, and to his fellow-men, he has announced that he will retire from his official position on 30 June 1954.

On the occasion of this announcement President Merewether introduced Dr. Brooks as "Mr. American Meteorological Society"—a designation that no one could have earned more fully than has Dr. Brooks.

Dr. Brooks' career has spanned all the tremendous development in meteorology that has been concentrated in the present century. He was born in St. Paul, Minnesota, on 2 May 1891. His university education was pursued mainly at Harvard University, where he received his A.B. in 1911 and his Ph.D. in 1914. There followed an active period in association with the Weather Bureau, the U. S. Army Signal Service, Yale University, and Clark University, and finally after 1931 at his present post as Professor of Meteorology in Harvard University. Dr. Brooks is also director of the Blue Hill Meteorological Observatory and the Mt. Washington Observatory. One needs only to peruse the *Bulletin* of the AMS and the *Monthly Weather Review* to realize that his pen has always been active in supplying both formal technical articles and popular items to scientific journals.

A further and probably more important phase of his career revolves around his unique personality. His warm sympathy for all men led him to give unstintingly of his time and energy to all who sought his advice regardless of their degrees or lack of degrees. He carried on a famous "postcard" correspondence with professional and amateur weathermen all over the world. And it was largely through his interest in popular aspects of the science that *Weatherwise* came into being in 1948.

All who know Dr. Brooks realize that he will never retire from the interest of his lifetime. We shall look forward to seeing him in the front row at AMS meetings for many years to come, taking notes and giving our young profession the unique continuity of his presence that has been so beneficial to all.

Vol. 7, No. 3 June, 1954

CONTENTS

Drought and Agriculture
— A. Vaughan Havens 51

Notes on the Climate of Indochina
— Capt. Robert W. Sanderson 56

Boston's East Wind
— F. Howard Rexroad 60

A Simple Index of Drought Conditions
— James McQuigg 64

The Vagaries of Spring 1954
— David M. Ludlum 70

551.5 73

Cover: Dr. Charles F. Brooks addressing the District of Columbia Branch of the AMS at the annual dinner in May 1953 in response to a resolution electing him to Honorary Membership and Honorary President of that Branch for life.

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A Kansas farmer in Hamilton County plows emergency deep furrows in his wheat fields in an attempt to save the soil from blowing—31 March 1954. Soil Conservation Service photo.

Drought and Agriculture

A. V. HAVENS, *Department of Meteorology, College of Agriculture, Rutgers University*

LESS than twenty years have passed since the droughts and dust storms of the 1930's laid waste to some 50 million acres of land in the famous Dust Bowl area of adjacent parts of Kansas, Oklahoma, Texas, New Mexico, and Colorado. Most intervening years have brought sufficient rainfall and record profits to the farmers and ranchers who survived the thirties. Recently, however, during the 15 weeks ending 29 March 1954, most of the region received less than 50 per cent and parts less than 25 per cent of the normal rainfall. This dry period, following rather widespread soil moisture deficiencies in 1952–53, have again caused serious drought damage in much of the area, and unless timely rainfall occurs soon another dust bowl as large or larger than that of 1936 is inevitable.*

It is well known that subnormal rainfall is not the only cause of drought and dust storm destruction. The natural vegetation of this region is deep-rooted grasses which are capable of surviving and of holding the soil in place in spite of occasional long dry spells. The big money producers of the region have long been wheat and beef cattle, and the "easy money" to be made from a wheat crop, particularly with governmental price support, has encouraged the cultivation of an additional 3.5 million acres since 1942, much of

* See Weatherwatch, page 74, for recent good news from the Dust Bowl.

which should never have been put to the plow. Furthermore, overgrazing of large sections of range land when soil moisture was not sufficient for recovery of the grass has left much additional acreage exposed to the drying winds, ripe for severe wind erosion and dust storm destruction.

In years with a normal 15 to 20 inches of rainfall drought and dust are not serious problems in this region except perhaps for brief periods in localized areas. It is only during extended periods of subnormal rainfall that crop failure and soil blowing take their heavy toll. Thus, rainfall is at the bottom of the drought problem in the southern Great Plains, even though the situation is seriously aggravated by the agricultural malpractices which are all too common in this region.

Regions Affected by Droughts

Fortunately, the Dust Bowl of the United States is small when compared with the portion of the country enjoying heavier and more reliable rainfall, and many countries on other continents suffer much more in this respect.

In order to describe the general regions of drought occurrence one should first define the term. To do so simply and precisely, however, is not easy. It is not possible to define a drought in terms of rainfall alone since many other factors are involved. One statistical study of droughts in the United States assumed that a rainfall of 0.1 inch or more within 48 hours would end a drought regardless of length, of soil moisture conditions prior, and of temperature, humidity, and wind during the dry spell. Such an assumption overlooks several important factors and could be very misleading.

The U. S. Weather Bureau, when confronted with the problem of defining droughts in the 1930's, found that the only all-inclusive definition was one stated in terms of the effects of dry weather on agriculture and other human activities. The definition of 1931 read as follows: "a lack of rainfall so great and long continued as to affect injuriously the plant and animal life of a place, and to deplete water supplies both for domestic purposes and for the operation of power plants, especially in those regions where rainfall is normally sufficient for such purposes." There certainly can be no argument with the completeness of such a definition, but to apply it in a regional study of droughts might prove difficult, because droughts are sometimes very spotty, localized phenomena. H. C. S. Thom in studying droughts in Iowa developed a separate definition of a drought for each county.

The last phrase of the Weather Bureau's definition—"especially in those regions where rainfall is normally sufficient for such purposes"—brings out an important point. It must be remembered that the natural vegetation and the agriculture of any region are more or less adjusted to the normal rainfall of that place. It is rare to hear a complaint about dry weather from a resident of a really arid region such as southwestern Arizona. Farmers of those areas expect dry weather and meet it through the use of irrigation and dry-land farming methods. The most destructive droughts have, almost without exception, occurred in those areas bordering on semi-deserts, where rainfall is not high, 15–20 inches per year, but normally sufficient to support a rather intensive agriculture. It is in these areas, such as the southwestern Great Plains, where infrequent, unexpected, and

Dust Bowl region—summer 1936

Incipient Dust Bowl—spring 1954

thus unprepared-for droughts cause desolation and destruction.

Drought Damage

C. F. Talman has stated that during the last 100 years in the United States, the period for which adequate records exist, the most severe droughts occurred in 1860, 1893–95, and 1930–31, 1934, and 1936, although the periods in between were interspersed by many individual dry years of less severity.

It has been estimated that 90 per cent of the settlers in the stricken areas of the Great Plains abandoned their land in the drought of 1893–95. During the droughts of the 1930's government aid prevented such a high percentage of abandonments, but still a tremendous emigration of financially-ruined families took place. The total wheat production of nine Middle Western states in both 1934 and 1936 was only about half of the 1928–32 average, and the corn crop was even more severely damaged.

The over-all effect of the current drought will not be known for some time, but preliminary reports gathered in late March present an alarming picture. The Soil Conservation Service estimated at this time that 16.8 million acres of land have been subject to soil blowing and severe wind erosion in the states of Colorado, Kansas, New Mexico, Oklahoma, and Texas. Recent reports from several counties of southeastern Colorado are typical of those coming from many sections of the old Dust Bowl area. Agricultural agents in Kiowa County, Colorado, estimate that $3.4 million in potential wheat profits have already been lost. In Baca County 70 per cent of a prospective 2 million bushel wheat crop has been destroyed, and in Cheyenne County 65 per cent of the cultivated land is now useless. These serious losses are, however, linked to unsound land-use practices. In Kiowa County, 440,000 acres were cultivated last year compared with 115,000 in 1930. Yet in spite of the resulting decrease in the acreage of grassland available for grazing, the cattle population has jumped from 14,000 in 1940 to 46,000 in 1952.

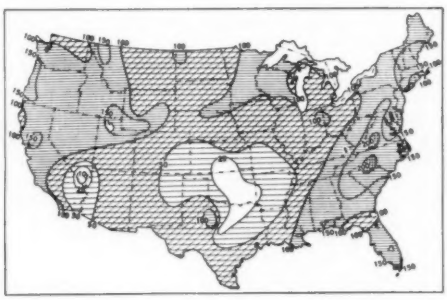
Thus, the danger of cultivating submarginal land and of overgrazing have both increased sharply, making the situation in some sections potentially more threatening than twenty years ago.

Why Droughts Occur

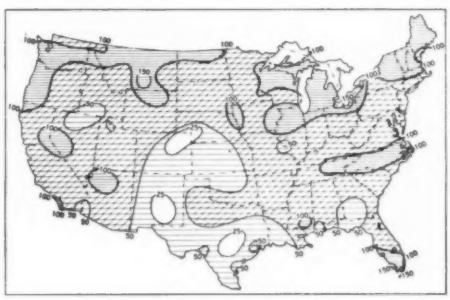
Certainly all will agree, that ultimately droughts result from the failure of those atmospheric processes which normally produce rain. But what are these processes, and why do they occasionally fail to operate?

The United States is very fortunate in having as its southern neighbors the warm Gulf of Mexico and the Caribbean Sea instead of a large subtropical land mass. The warm, humid, maritime tropical air which forms over these two water bodies is by far the most important source of the rain which falls in the Great Plains, as well as over most of the country east of the Rocky Mountains. During the cold season from November to March this air mass is seldom found at the surface, except along the Gulf Coast and in the extreme Southeast. Although this is normally the dry season in the Great Plains, some rain results when tropical air is forced upward over colder Canadian sub-polar air masses by cyclonic and frontal activity.

Most of the rainfall of the Great Plains occurs during the warm season from April to



January–April 1936



19 weeks ending 26 April 1954

Percentage of normal rainfall

October. In summer Canadian air reaches the Great Plains much less frequently and is neutralized to a much greater extent than in winter and spring. Although frontal and cyclonic activity are not completely absent in summer, air mass contrasts are much less pronounced, and rainfall from this source is relatively unimportant. Instead, warm, humid, tropical air normally dominates the weather map. Most of the warm season rainfall results from convective showers and thunderstorms which develop in the unstable tropical air as it moves northward over the heated continent.

The normal trajectory of this all-important air mass after leaving its Gulf source region is northward and slightly westward over the continent and thence northeastward as it moves into the mid-latitude zone of prevailing wesferlies. The Great Plains west of the 100th meridian are located just on the edge of this normal path and thus are subject to large fluctuations of rainfall depending to a great extent upon how far northward and westward the flow of tropical air is reaching. This in turn depends largely on the speed and persistency of the prevailing westerlies, that is, on the intensity of the general atmospheric circulation. This situation is somewhat similar to that in northern China where severe droughts result from the periodic failure of monsoon rains to penetrate as far northward and inland as they normally do. The air mass involved here is also of tropical origin from the southwest Pacific. The intensity of the westerlies undergoes a seasonal fluctuation and is normally strongest in winter. There is, however, a great deal of variation from year to year, and when unusually strong and persistent westerly flow dominates the weather pattern, Gulf air follows a more easterly path and thus bypasses the region between the 100th meridian and the Rocky Mountains. Then this area is controlled almost entirely by dry air masses—in the cold season by cold, dry Canadian air and by Pacific air which has lost its moisture on the western slopes of the Rockies and been greatly warmed by its descent to the Plains, and in summer by hot, dry, continental tropical air from the arid Southwest, an air mass that is involved in the infamous "hot winds" which are so devastating to crops and livestock during a drought.

Before the air mass concept of the lower atmosphere had been generally accepted in this country, many meteorologists placed a great deal of emphasis on local factors. One writer went so far as to state, in 1931, that once soil moisture had become depleted and rivers and lakes had dried up, the decrease of surface evaporation was the predominant factor in preventing the occurrence of the normal summer shower and thunderstorm activity. If this were true, it would mean that a drought, once established, would have a strong tendency to perpetuate itself. We know now, however, that the dynamic influence of the large scale atmospheric circulation is by far the most important factor, for it is capable of ending the most severe drought almost overnight, merely by a change in the prevailing pressure pattern and thus in the predominant air masses. The decrease of local evaporation during a drought is important, however, since it doubtless has an intensifying effect although its self-perpetuating influence is probably negligible.

If the large scale pattern of the general atmospheric circulation is the controlling factor in drought occurrence, the questions naturally arise: what causes changes in the circulation pattern, and what are the possibilities of forecasting these changes?

Can Droughts Be Forecast?

If a drought could be forecast a year, or even a season, in advance with reasonable accuracy, timely action by farmers, ranchers, and government agencies could effectively minimize drought damage.

Most efforts in this direction have involved the examination of various indications of long-period climatic fluctuations, including data on glaciers, lake levels, tree rings, and the migration of population due to drought, flood, excessive heat or cold, as well as all available weather and sunspot records. The object is, of course, to discover the possible existence of a climatic cycle or cycles of definite length and amplitude which would at long last solve this long-range forecast problem. Results to date have yielded claims for the existence of hundreds of cycles varying in length from a few months to hundreds of years, with the shorter ones superimposed on the longer ones, creating an over-all picture of bewildering chaos and confusion.

One writer in 1934 claimed the co-existence of cycles of 35, 83, 300, and 1400 years in length and that the 35-year cycle had the greatest amplitude and was therefore the most noticeable and most effective. Furthermore, he claimed that there would be a near coincidence of the dry phases of all these cycles in the early part of the next century. On this basis he forecasted that the period 1950–55 would be cool and wet, that the early 1970's would bring even worse droughts than those of the 1930's, and that the most severe droughts in history would occur about 2005 A.D. This is just one example of the extremes to which the "cycle" approach has been carried, although it is very doubtful whether any of the proposed cycles could withstand the modern tests of "statistical significance."

Thus, there is little hope for successful long-range forecasts of droughts in the foreseeable future. In addressing a meeting of agricultural scientists in March 1949, the writer stated in part, "It is almost a certainty that droughts will come again to the Great Plains region, but any attempt to forecast exactly when (they will occur), or how severe (they will be), must remain for the present little more than a guess." This statement was made not at all as a forecast in the meteorological sense of the word, although a brief five years have proven it to be tragically prophetic.

Can Droughts Be Prevented?

Research on cloud physics during World War II and the following years has made it possible under certain ideal atmospheric conditions to "seed" clouds with various substances and to cause earlier and perhaps slightly heavier precipitation than would have occurred naturally. While considerable controversy has been and still is going on regarding the extent to which weather modification can be successfully accomplished, most un-biased experts agree that cloud seeding in its present state of development is in the nature of a "trigger" action which is usually successful only in situations which are favorable for the occurrence of natural rainfall. Whether it is now or will ever be possible to increase rainfall in economically significant amounts remains a highly speculative matter.

(*Continued on page 68*)

The grass atop a hummock in Holt County, Nebraska, indicates the former level of the prairie. About three feet of soil have been lost through wind erosion. Soil Conservation Service photo.

Notes on the Climate of Indochina

CAPT. ROBERT W. SANDERSON, *Directorate of Climatology, Air Weather Service*

WEATHER, not the British navy, defeated the Spanish Armada.—Russian weather, not the Russian armies, defeated both of Europe's "Little Corporals."—To a large degree, weather is today dictating the conduct of military operations in the Indochina conflict.

In this era of technological warfare, the military planner must be ever conscious of the "weather factor" in operational planning. An accurate forecast of future weather conditions would, of course, best answer the need for this intelligence. Unfortunately, no method of accurate long-range forecasting has yet been developed. The best tool the planner can employ in evaluating the effect of weather on his operation is climatology. While this short study of the climate of Indochina can never serve to answer specific questions in campaign planning, it will introduce the reader to a general knowledge of the weather regime of the area.

Two broad principles are immediately evident. In Indochina, the winter months are most favorable for military campaigns, while the heavy summer rains generally restrict the modern military machine.

The climate of Indochina is controlled by its geographical location. Lying within the tropical zone of the Northern Hemisphere, it is subject to the seasonal influences of the Pacific Ocean trade winds. In addition, its position relative to the huge land mass of Asia brings it under the influence of the Asiatic monsoon structure.

The physiography of the country also acts as an important climatic control. The northern Shan Plateau, the Annam Highland which forms the backbone of the country, and the Darlac Plateau and Cambodian Ranges in the

south form a barrier to the prevailing wind systems. Most variations in the general climatic picture can be traced to the blocking and sheltering effects of these uplands.

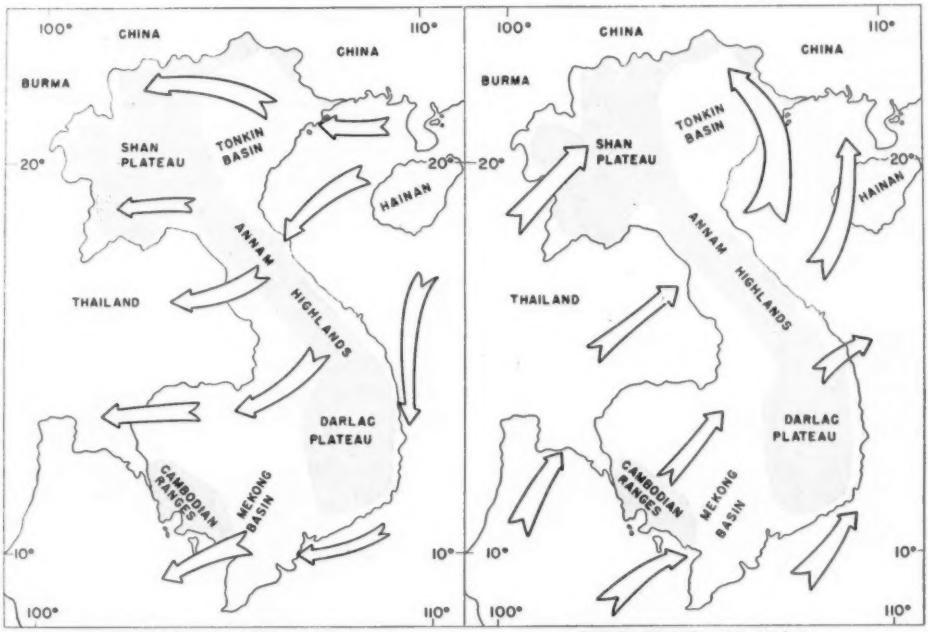
Two pressure systems affect Indochina. From November through April, the country is dominated by the winter (northeast) monsoon. This circulation develops gradually during the autumn transitional period, being introduced by a series of strong cold air outbreaks that move southward from China. These outbreaks bring widespread rain and low cloudiness to the Tonkin Basin and to the coastal regions of Tonkin and Annam.

By late January the winter monsoon weakens slightly, and a local weather phenomenon called the "crachin" dominates the northeastern portion of the country. Being characterized by low stratus clouds, light rain or drizzle, and poor surface visibility, the "crachin" may persist for as long as three weeks. The normal pattern, however, is for recurring periods of three to five days each. The entire Tonkin Basin, the Annam and Tonkin coasts, and the foothills of the Shan Plateau are subject to the "crachin," and can expect such weather on 10 to 15 days per month throughout the winter monsoon season.

Due to the blocking effect of the uplands, the interior, the western, and the southern portions of Indochina enjoy relatively fair weather during the winter.

April and May are transitional months, with diverse and changeable weather occurring over the entire country. At this time the northeast monsoon flow is being challenged by a strengthening southwest wind. Either may dominate, bringing its characteristic weather patterns to the area. The thunderstorm makes its first significant appearance at this time, especially over the north and central interior regions.

The arrival of the summer (southwest) monsoon over Indochina is not nearly so marked, or so dramatic, as is its arrival over India. A definite weather change, however, does occur in a relatively short period. By mid-April the convective thunderstorm is evident almost every afternoon over the western portion of the country. By the middle of May the transition is complete, and heavy thunderstorms and showers are a daily occur-



PREVAILING SURFACE FLOW

rence. These storms, a product of the combined effects of circulation, orographic lift, and convective heating, are especially violent along the southwestern slopes of the Annam Highland and the Shan Plateau. Nocturnal thunderstorms are most frequent over the Mekong Valley, where convection is the major triggering force in their formation.

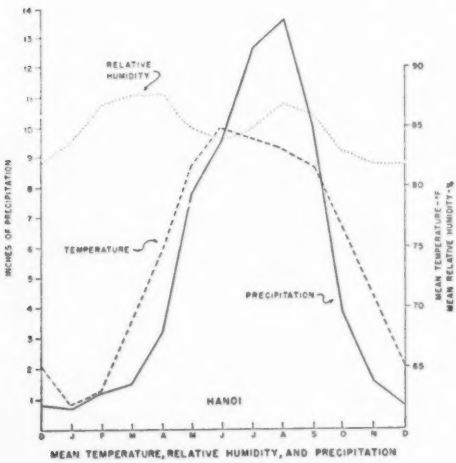
During the summer, the east coast of Indochina frequently experiences comparatively clear and dry weather, again a result of the blocking effect of the north-south mountain chain that traverses the country.

The autumn transitional season in September and October brings widely varying conditions. Heavy showers are frequent in the south and along the southwest coast, accompanying certain maritime disturbances which traverse the area from east to west at this time. Over the balance of the country the weather is varied and changeable, just as during the spring transitional period.

Such is the seasonal character of the climate of Indochina. The individual weather elements, except for relative humidity, follow similar patterns.

Temperatures characteristic of tropical areas prevail over most of the country, with semi-tropical readings in the north and at high elevations over the balance of the country. Saigon in the south and Hanoi in the north are representative of these two zones.

In the north, winters are cool with mean temperatures in the mid-fifties to mid-sixties. Elevation determines whether a station is in the upper or lower limits of this scale. Hot summers are the rule with mean temperatures in the mid-eighties. The diurnal range is small, averaging 10 degrees in winter and slightly more in summer. April is the warmest month, with a slight decrease accompanying the summer cloudiness and rain.



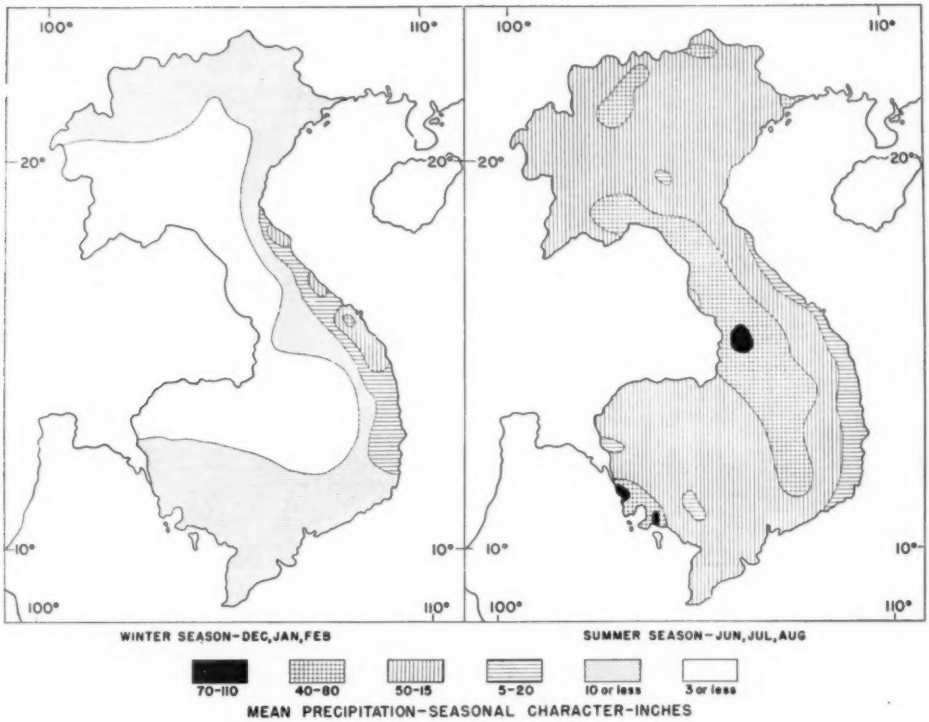
The southern half of the country experiences a similar regime with April the hottest month and a secondary hot season in early autumn. Summer mean daily maximum temperatures are in the mid-nineties, the diurnal range averaging 12 degrees in the lowlands and up to 30 degrees at mountain locations. In winter the mean temperature is about 70° F with daily maxima in the mid-eighties. The diurnal range is from 15 to 20 degrees.

Extremes of temperature range from 28° to 113° F. Maximum temperatures above 90° F are not reached above 5,000 feet. Freezing weather is rare, occurring only in the extreme north and at elevations above 4,000 feet in the south in winter.

The element with the smallest yearly range is relative humidity. As an example, the mean monthly relative humidity at Hanoi ranges from 82 to 88 per cent. Relative humidities below 50 per cent are rare, occurring occasionally in the western portion and at mountain stations throughout the country during December, January, and February. The average relative humidity for the entire nation is 70 to 90 per cent.

This combination of high temperature and high relative humidity results in an oppressive, enervating climate that greatly restricts human activity. Perspiration does not evaporate. Clothing will not dry. Shoes and other leather goods mildew and rot quickly. Any surface susceptible to corrosion is quickly pitted. All in all, a poor climate in which to live, much less fight a war.

The heavy rainfall adds to the trials and tribulations of the inhabitants. The average rainfall over the country is 50 to 80 inches, the extremes from 30 to 160 inches. While these totals are not among the world's highest, the seasonal character of the precipitation increases the moisture problem. A major portion of the precipitation falls during the months of June, July, August, and September. During this period the monthly rainfall is from 15 to 30 inches, while in



winter the average is only 2 inches, with no station receiving more than 6 inches of precipitation per month.

The record annual rainfall occurred at Kas Kong in 1923 when 313 inches was recorded. Dien Bien Phu reported 131 inches of rain in the two months of July and August 1937. In September 1930, Latrong had 115 inches of rain, and Hatien, on the southwest coast, once received over 28 inches of rain in 24 hours. A typhoon is responsible for the hourly rainfall record, flooding the Tonkin Basin station at Phu Lien with 4.35 inches in one hour, 8.66 inches in 3 hours, and almost 24 inches of rain in one day.

While the amount of precipitation is seasonal, the number of days with precipitation is fairly uniform throughout the year, though a slight summer maximum is noted except in the Tonkin Basin. There the "crachin" brings a maximum of rainy days in winter. The drizzle accompanying this phenomenon, however, accounts for only a small portion of the yearly rainfall.

Almost all precipitation falls as rain. Snow is rare and confined to the extreme northern portions of the Shan Plateau.

The areas and seasons of maximum cloudiness over Indochina coincide with those of maximum rainfall with the exception of the Tonkin Basin. In that area the "crachin" causes a winter maximum of cloudiness. This Basin also has much cloud cover in summer, thus being the area of maximum cloud cover on a yearly basis.

Ceilings are generally not below 1,000 feet except during the "crachin" in winter. At those times, cloud bases may be as low as 200 feet, with fog occasionally aiding in forming "zero-zero" weather. Ceilings under the summer cumulus are generally from 1,000 to 3,000 feet except, of course, in shower areas. Since the summer thunderstorms are usually rather scattered in distribution, aircraft flights through and around them are feasible, but heavy turbulence would make such flights most uncomfortable. Low-level flights under

(Continued on page 69)

Boston Harbor and Logan Airport. Courtesy Fay Photo. Service Inc.

Boston's East Wind

F. Howard Rexroad, *U. S. Weather Bureau, Boston*

THE sea breeze is one of many types of local winds whose character and occurrence depend upon geographical location. The fame of Boston's East Wind thus does not derive from any singular qualities in the circulation over Massachusetts Bay, but rather from the fact that Boston combines in a rather unusual way a highly concentrated population and an extensive natural cooling system. Along the New England coast, the sea breeze becomes important as early as March and continues to provide both comfort and conversation into September. Its greatest frequency and strength occur in the late spring and early summer when the land-sea temperature contrast is at a maximum.

To many New Englanders a shift in the wind to an easterly direction is known as the "sea-turn." Ordinarily, this term is applied to an east or northeast wind following the passage of an east-west cold front. Such a wind is, of course, a reflection of the general pressure gradient, and its cooling effects are felt throughout the interior of southern New England. Low cloud, drizzle, and fog sometimes accompany the sea-turn which, contrary to the sea breeze, may occur at any time of the day or night. At times, an east-west cold front through southern Maine, New Hampshire, and Vermont has a weak pressure gradient ahead of it, permitting a sea breeze to develop along the Massachusetts coast. In

these cases, a preliminary cooling, restricted to the immediate coastal area, precedes the more marked temperature drop accompanying the true sea-turn.

The sea breeze develops because of the much stronger heating of the air over the land compared with the air over the water. This differential heating arises largely because of the unstable nature of the sea whose surface particles, through wind and wave action, are continually being replaced by subsurface particles. Thus the temperature of the sea surface and consequently of the air immediately above it changes but little during the day. It would be expected that such a difference in heating would bring about a local wind effect. With convection occurring over land, a certain amount of divergence aloft would cause some of the rising land air to flow out over the sea, resulting in relatively higher surface pressure over the water than over the land. The result is the addition of a small but significant periodic pressure gradient force to the general pressure gradient over the coastal region. The period of this additional force closely approximates the period of the daily temperature curve. The combined effects of this periodic force and of friction cause the sea breeze to reach its maximum velocity at about the time of the maximum temperature inland.

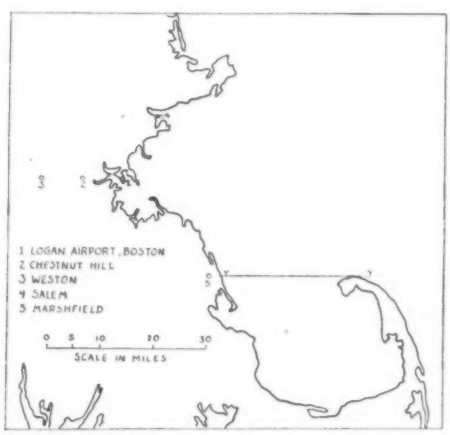
Whether or not a sea breeze will develop depends also on the undisturbed general or gradient wind direction and velocity. When this is strong offshore, a sea breeze is unlikely. At Boston, where the water is principally to the east, gradient winds from the north through east to south are most favorable for sea breeze development, while west and northwest winds are least favorable.

Likewise, variations in water temperature will have an effect upon the formation of the sea breeze. Offshore winds and ebbing tides both operate to lower the temperature of the sea surface. This occurs by the process known as upwelling, whereby the layer of water at the sea surface is carried away from the coastline and is replaced by relatively colder sub-surface water. The effect of onshore winds and incoming tides on the sea surface temperature along the coastline is not as simple because of the considerable irregularity in the sea surface temperature in Massachusetts Bay where some sections are always warmer than others. Thus east and southeast winds bring warmer surface water into Boston Harbor, while northeast winds bring colder water.

These several more or less erratic factors make the forecasting of the sea breeze at Boston not readily reducible to a quantitative basis. One empirical rule is that with a westerly gradient, a sea breeze is likely at Boston when the pressure at Portland, Maine, 100 miles to the north northeast, is not much more than a millibar less than the pressure at Boston.

Some specific characteristics of the sea breeze at Boston should be emphasized. First, it should be noted that the development may be either gradual or abrupt. The gradual development usually begins in the early morning. In such cases the sea breeze serves to keep the maximum temperature along the coast at a level considerably below representative inland maxima. On the other hand, the sea breeze which appears abruptly often does so after coastal temperatures have risen to about the same levels as inland temperatures. Such a sea breeze shows many frontal characteristics, involving as it does abrupt changes in not only the wind but also in temperature and humidity, and even at times a small but distinct rise in pressure.

Examples of these two types of sea breeze development is illustrated. On 20 July 1952, the onset of the sea breeze was delayed until early afternoon when the temperature at



Massachusetts Bay area.

Logan Airport in Boston Harbor had risen to 90° F., a reading very close to the highest temperatures reported from inland stations. Gustiness was reported in the surface wind between 0930 and 1430 EST, but for purposes of clarity only the mean wind during this period is shown. The abrupt rise in humidity accompanying the quasi-frontal type of sea breeze is clearly evident.

The approach of this type of sea breeze from some distance offshore has frequently been described by those who have observed it from a beach. The ripple produced on the sea surface has been likened in appearance to that made by a school of mackerel. Others have noted the landward progress of the breeze by observing its effects on small sailing vessels at different distances offshore.

On 30 July 1952, the sea breeze development was gradual, beginning at 0730 EST. On this day the highest temperature at Logan Airport was only 72°, while at Chestnut Hill and Weston, 8 and 15 miles inland, the highest temperatures were 86° and 87°.

It must be emphasized that the sea breeze is a highly local phenomenon, resulting in many variations along the numerous indentations of the New England coast. For example, on many occasions a sea breeze has developed at Salem, Mass., but not at Logan Airport, 12 miles to the southwest. An instance occurred on 28 July 1952, when a sea breeze began at Salem at about noon. During the rest of the day the temperature recorded at the Salem Coast Guard station remained in the upper 70's, while at Logan Airport the temperature was in the low 90's.

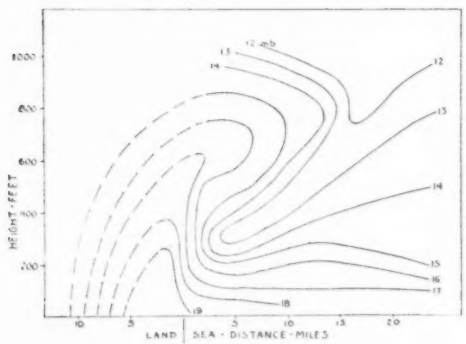
A characteristic feature of the sea breeze in temperate latitudes is the gradual veering of the wind during the course of the day, so that at the end of the day the wind blows parallel to the coast. At Boston this feature is shown clearly in the mean hodograph of 40 sea breeze occurrences during the summer of 1944 as observed by an Air Weather Service project. This turning of the wind during the day is caused by the Coriolis force.

Some average values for the sea breeze at Boston, based upon 1944 observations at Logan Airport, follow (Indicated times are Eastern Standard):

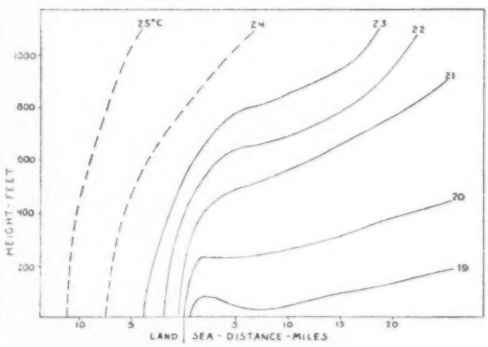
General gradient wind	Westerly		Easterly		All Cases	
	Mean	Range	Mean	Range	Mean	Range
Onset time	1030	06–20	0830	04–16	0930	04–20
Onset time, hours after sunrise	6.0	2–16	3.5	0–11	5.0	0–16
Cessation time	1730	11–23	2000	17–23	1830	11–23
Duration, hours	7.0	1–12	11.5	4–17	9.0	1–17
Max. velocity	12	5–20	13	7–20	13	5–20
Time of max. vel.	1400	10–21	1330	08–19	1400	08–21
Number of cases	37		24		61	

The duration of the transition period from land to sea breeze was found to vary from only a few minutes, in the case of the abrupt frontal type, to as much as two hours in the type where the development was gradual.

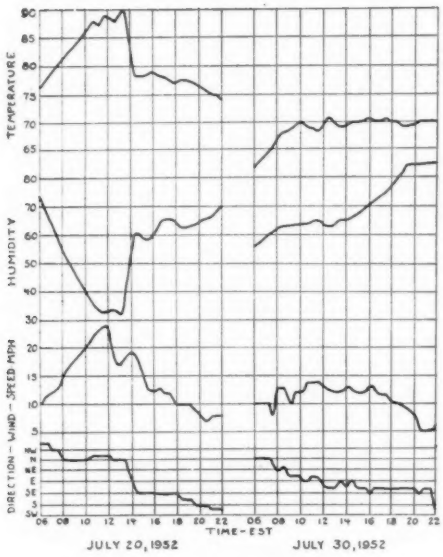
The distance inland that the sea breeze will penetrate depends upon the general gradient wind as well as upon daytime heating. Relatively weak offshore gradients favor greater penetration, but here too no precise rules are available. A much earlier study by Davis, Schultz, and Ward in 1888 indicates a maxi-



Vapor Pressure Distribution, 5 July 1944



Potential Temperature Distribution, 5 July 1944



Boston Sea Breeze Meteorgrams

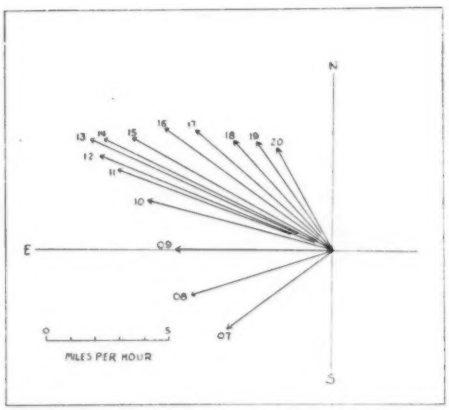
mum penetration along the Massachusetts-New Hampshire coasts of 22 to 25 miles. As would be expected, at such distances only a slight reduction in temperature is to be noted.

In connection with another study by Craig, Katz, and Harney in 1945, a series of measurements of the temperature and moisture in the lowest 1,000 feet of the atmosphere over Massachusetts Bay was made by airplane and balloon during the summer and fall of 1944 by the MIT Radiation Laboratory. Some of these observations were made during sea breezes. The result of one set of observations is shown in accompanying charts. Moisture is indicated as vapor pressure in millibars, and temperature as potential temperature in degrees Centigrade referred to sea level rather than to the more usual 1000 mb. The soundings were made along the line Y-Y on the map. Although the soundings were not simultaneous, only about one hour separated the first at 1002 from the last at 1107 EST. The pilot balloon observations at Boston indicated westerly winds at 1,000 feet at both 0430 and 1030, with velocities of 10 mph and 4–6 mph respectively. Since the sea breeze began at 0730 at Marshfield, it had not been long established at the time of the cross sections. The dry air between 200 and 500 feet may have left the land at that level before the sea breeze started, or at higher levels after it began, reaching the indicated position by subsidence. In either case the diagrams give some idea of the vertical currents involved in the sea breeze circulation.

The sea breeze at Boston may affect the visibility in either of two ways. In the first place, there may be patches of dense fog over the water a short distance offshore. With the onset of the sea breeze, some of this fog is carried onshore. As a result, aviation weather at Logan Airport changes abruptly from unlimited ceiling and visibility to near zero conditions in a very few minutes. The sea breeze fog may also blanket Boston Harbor, bringing not only aviation but also sea traffic to a halt. If the fog is rather shallow, and if the sea breeze is delayed until early or midafternoon, then the fog may affect the airport only intermittently or even partially, with less than half of the field covered. Sea breeze fog, while dramatic in its appearance and effects, is not a very common thing at Boston, occurring only a few times each season.

On the other hand, the sea breeze may cause an improvement in the visibility. With light westerly winds during the night, smoke and haze tend to concentrate along the coastline and a little distance offshore, reducing the visibility to 2 or 3 miles during the early morning hours. The visibility in such cases ordinarily improves gradually after about 0800. With the onset of an early morning

(*Continued on page 67*)



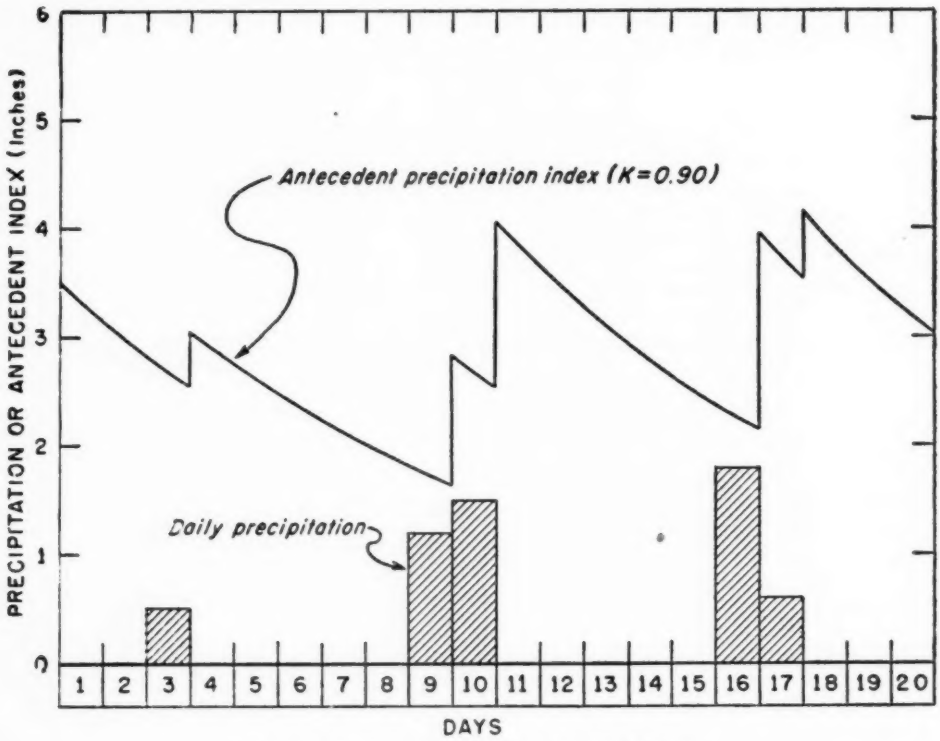
Mean Sea Breeze Hodograph

A Simple Index of Drought Conditions

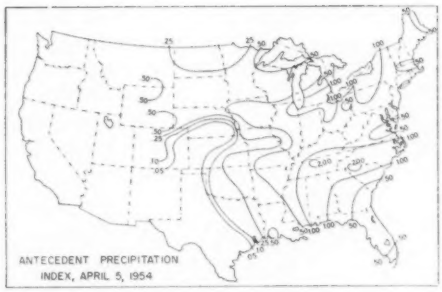
JAMES MCQUIGG, *U. S. Weather Bureau, Washington*

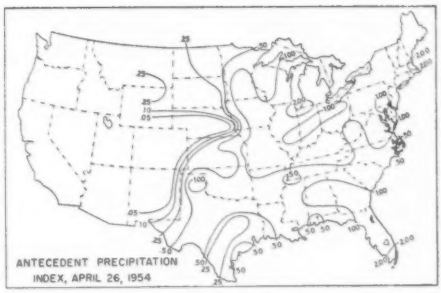
THE dry weather which has prevailed in several parts of this country in recent years has awakened a considerable amount of interest in the study of drought conditions. In addition to theoretical inquiries into the causes of droughts and studies of forecasting methods, there is need of a fairly simple technique for following the progress of current drought conditions, and of a way to evaluate the relative intensity of a current dry spell. Among a great number of "drought indexes," which attempt to take into account both the amount and timing of the rains, the following describes a promising method being tested by the Weather Bureau at the present time.

In order to estimate how much water can be expected to run off into the streams in a river basin following a rain, the River Forecast Centers need to know the moisture condition of the soil in the basin just before the rains commence. One way to have such data available would be to make regular measurements of soil moisture at several locations in the basin; but this method is not used, mainly because of the cost of keeping up such readings each day. Several other methods have been used, such as estimates based on the number of days since the last rain, and evaluations based on stream flow and the level of ground water in the basin. The first leads to difficulties in trying to account for the difference between a situation in which the "last rain" was big and one that was small. The second method is not always sensitive to rains which occur within the week just prior to the rain under consideration.



Variation of antecedent index with daily precipitation.





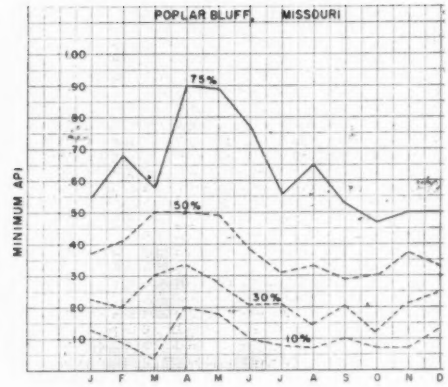
The third kind of data is not easily available on a daily basis.

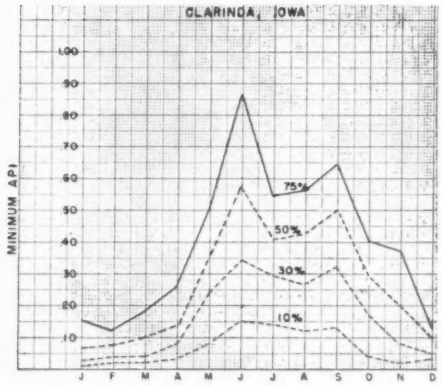
To meet the need for a quick, objective method for estimating the moisture condition of the soil just prior to a rainstorm, using data readily available each day, an "Antecedent Precipitation Index" is used as described in detail in *Weather Bureau Research Paper No. 34*. Essentially the index is computed on a daily basis by multiplying the index for the previous day by a factor, usually 0.90. If rain occurs on any day, the amount of rain observed is added to the index. To begin the calculations, it is customary to assume an initial index of the normal ten-day total rainfall for the weather stations involved and for the time of year. By the time the index computations have been made for four or five weeks, the computed value will closely approximate the actual value. Snowfall is handled by accounting for it on the day it melts. Linsley and Kohler point out that some refinements might add to the elegance of the computations, such as using "precipitation minus runoff," instead of "precipitation," and allowing for variations in temperature, dew point, wind, evaporation, and for the physical characteristics of the basin. But for all practical purposes the described method gives good results over most of the eastern and central portions of the United States. The rainfall data used are easily available on the weather teletypewriter networks, if you are planning to follow the progress of the index over large sections of the country. Local data would be available from your own rain gage or from your nearest weather observer.

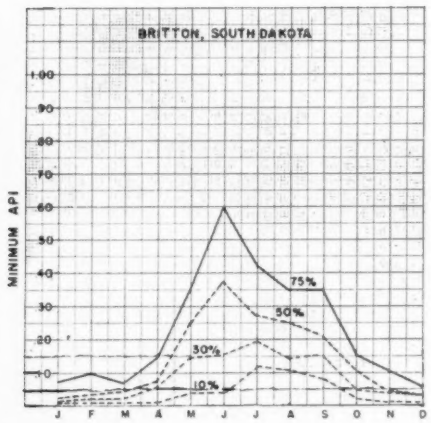
Since the Antecedent Precipitation Index (hereafter referred to as API) gave good practical results in working with stream-flow data, it was decided to test its usefulness in evaluating the cumulative effects of rainfall in the preparation of crop-weather summaries and in studying drought conditions. The first phase of this test has involved the preparation of current charts showing the values of API for about 100 weather stations east of the Rockies. Two sample charts are shown for 5 April and 26 April 1954. The lowest API values on the charts indicate the areas undergoing the most intense dry weather as of the day they were prepared. The advantage of such charts is that they take into account both the amount and the timing of rains that have occurred in recent weeks. Charts showing only the total amount of rain over a period of weeks do not indicate whether such rains fell early or late in the period, or were spaced evenly throughout the period in question.

The second phase of the test involved the computation of API values for a 30-year period for a number of stations in South Dakota, Iowa, and Missouri. These were chosen because daily rainfall data were readily available on punched cards, which made it possible to use machine processing of the computations.

Monthly and annual cumulative frequency distributions of these daily values of API were prepared. From these it is possible to relate current values with those experienced in the past, to determine whether the current values are running higher or lower than might be expected from past experience; and if so, how much higher or lower. The question arises during every prolonged dry spell—"Was this the driest such period of record?" Total rainfall during the period will not al-





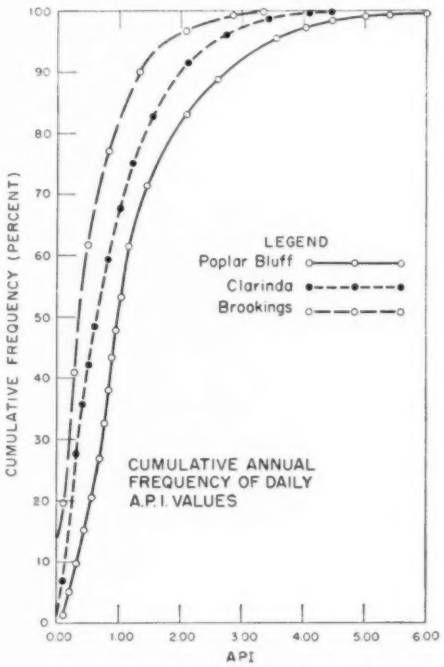


The probability of the occurrence of minimum antecedent precipitation index at three stations subject to drought.

ways show the true picture because the timing is almost equally important. Annual cumulative frequency curves are shown for Poplar Bluff, Missouri, Clarinda, Iowa, and Britton, South Dakota. These demonstrate the expectancy of more spells of dry weather at Brookings than at the other two locations.

A tabulation was made of the minimum API value for each calendar month, and from these the frequency of occurrence of the various minimum values was computed, showing the minimum values which occurred in 75%, 50%, 30% and 10% of the years studied. Some estimate of minimum values to be expected in future years can be made from these charts, which can be used also to determine the relative intensity of a dry period just past.

As a further test, 32 years of corn yields for Black Hawk County, Iowa, were compared against the minimum value of API experienced each year during the period mid-May to mid-August. The yields were first corrected to account for increases over the years because of improved seed, better soil management, and improved farm practices.

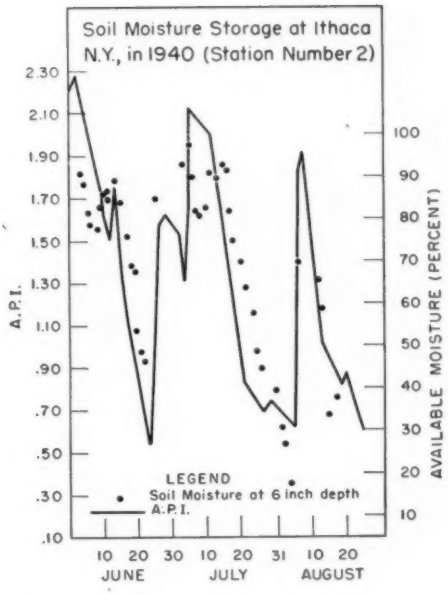


The results are shown in the following table:

Minimum API mid-May to mid-August	Number of Years Above "normal" Yields	Below "normal" Yields
.00 to .10	None	3
.11 to .20	3	4
.21 to .50	14	5
.50 to .80	0	3

The poorest yields occurred in years when the index dropped below .10 and in the wet years when it failed to go below .50 during mid-May to mid-August. Finally, values of API were computed using daily rainfall data at Ithaca, N. Y., station No. 2, for 1940, and plotted as a time series on the same graph with soil moisture readings taken at a depth of six inches by use of Bouyoucos gypsum blocks at Ithaca in the same year. This graph suggests a fairly good relationship between API values and the soil moisture conditions between the surface and the 1-foot level, at least at Ithaca, N. Y. These soil moisture data were kindly furnished by John R. Mather and published in the February 1954 *Bulletin of the AMS*.

We have found this index useful as a quick, simple technique for studying the cumulative effects of rainfall. *Weatherwise* readers might be interested in keeping up a tabulation of



API values during the coming summer and in comparing these against values which can easily be computed for several past years, including some dry ones and some with above normal rainfall.

Boston

(*Continued from page 63*)

sea breeze, the visibility is briefly reduced somewhat, as at first some smoke and haze are blown back on shore. This is followed, however, by an abrupt clearing away of the smoke and haze as the much cleaner ocean air overspreads the coastline.

To the average individual, the most significant feature of the sea breeze is of course its invigorating effect. This is most noticeable in the frontal type which may cause the temperature to plummet as much as twenty degrees in only a very few minutes and bring relief from an enervating hot spell.

The sea breeze is most welcome during a heat wave. If a sea breeze develops on several days during such a period, at least temporary relief is afforded those who are fortunate enough to come under its influence. Such a situation occurred at Boston during the latter part of June 1953. From the 19th to the 30th, representative inland maximum temperatures were generally well above normal, ranging from the upper 80's to the middle 90's, except on two days. While there were a number of frontal passages during this period, the post-frontal air was generally so modified by the time it reached New England that the change in air mass was reflected only slightly in the maximum temperatures. On three days during this period sea breezes at Logan Airport reduced the afternoon temperatures to the upper 60's or middle 70's, as much as 25 degrees lower than concurrent inland readings. On three other days sea breezes were established early in the day, but were overcome at Logan Airport during the late afternoon as the general pressure gradient strengthened. On these days the sea breeze remained active along the coastline immediately northeast of Boston, where late afternoon temperatures averaged about 10 degrees below those elsewhere in the area.

Drought (*Continued from page 55*)

Certainly cloud seeding will never succeed in precipitating moisture from a dust cloud!

Conservation Needed

Since droughts cannot at present be forecast, and since cloud seeding offers little hope of a reliable solution, either on a regional basis or for the individual farmer, the keynote of the agriculture of the Midwest should be one of conservation. When drought conditions begin to develop the Great Plains agriculturists should forget about raising a money crop and should be content if they can successfully accomplish two things. First and foremost, they should do everything possible to protect their land from the ravages of severe wind erosion, and secondly, they should attempt to prevent complete crop failure. Conservation practices can do a great deal toward successful accomplishment of these two goals during all but the most severe droughts.

(1) Maintenance of a vegetative cover on the land at all times. Some of the methods recommended for this purpose are: crop rotation, controlled grazing, and stubble mulching.

(2) Prevention of surface run-off. This can be very effectively accomplished by terracing, contour tillage, contour furrowing of range land, and strip cropping. Experiments with terracing and contour tillage at Goodwell, Texas, increased average soil moisture 25 per cent, resulting in a 35 per cent increase of crop yield. In 1935–37 the demonstration areas of the Soil Conservation Service in the southern Great Plains produced crops successfully on as little as 12 inches of rainfall annually by use of these methods. At this time it was estimated that of the 64 million acres of range land in the southern Plains, more than 50 per cent could have been greatly benefited by contour furrowing.

(3) Reduction of the loss of moisture by evaporation. The only effective method of reducing evaporation from the soil and transpiration of moisture from vegetation involves the use of shelterbelts of protective tree plantings to decrease wind speed. C. G. Bates has shown that shelterbelts, if planted during favorable weather and managed carefully, can be grown successfully in most places on the Plains. Their effective reduction of wind speed not only decreases evaporation, but also holds snow on the protected area, making it available to increase soil moisture during the critical spring planting period. Shelterbelts are also effective in reducing soil blowing, lodging or mechanical injury to crops by wind, and fuel consumption in heated buildings. They also provide excellent shelter for livestock and wildlife.

(4) Provision of supplemental irrigation. Although there are many different ways of accomplishing this aim, perhaps the most common one involves the construction of small artificial ponds or stock tanks placed so as to catch water which would otherwise be lost as surface run-off. C. W. Thornthwaite's moisture studies have shown that even in the Southeastern states, where abundant rainfall would lead to the belief that there is never a water shortage, 80 per cent of the years show a period of soil moisture deficiency during some part of the growing season. He concluded that all sections of the country could make use of supplemental irrigation at certain times. Whether or not it is economically sound to irrigate, however, must be decided on an individual basis. As far as the Great Plains are concerned, the availability of even small amounts of additional water in dry years would often mean the difference between a crop and no crop.

Too much water is a rare occurrence on the Great Plains, but conservation methods are equally beneficial in minimizing the ill effects of excess water, such as severe soil erosion and floods. Furthermore, the resulting increase of soil moisture storage enables crops to survive shorter and less severe dry periods. Thus, the continuous application of these methods is at present the only answer to the problem of recurrent droughts.

Indochina (*Continued from page 59*)

these storms are also possible, but must be made with care since showers will often lower visibility and ceiling to less than contact flight minimums. Summer flights are generally of the "duck and dodge variety," dodge the showers and duck the clouds.

The typhoon, though spectacular in its destructive power, is not a major factor in the climatic picture. These storms are extremely rare between January and March, becoming fairly frequent in September and October. Typhoons are a problem only along the coast, dissipating rapidly as they move inland. The following table, based on a 25-year period of record, illustrates the total and monthly frequency of the typhoon in Indochina:

Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1	4	8	13	6	26	31	14	5

What is the effect of this climatic picture on military operations? The answer lies in the seasonal character of the climate in general and the rainfall in particular.

Ground operations are hampered the year around by poor soil trafficability. Even in the relatively dry winter season the movement of wheeled vehicles over other than surfaced roads is difficult, particularly so in the Tonkin Basin area. The flooded rice paddies that border the roads offer no alternative paths if the roads themselves are impassable.

Special tracked equipment and special techniques, however, will allow a mechanized army to conduct large-scale operations in the Tonkin area, and over the balance of the country conditions in winter are at their best for large-scale military campaigns by a mechanized army.

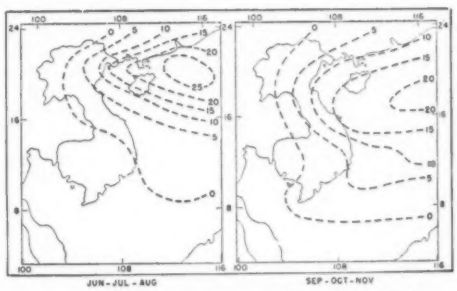
Likewise, the winter season offers the best opportunity for air support operations. The interior and western portions of the country are relatively clear, offering almost unlimited opportunity for tactical or strategic air operations. The Tonkin Basin is, of course, plagued by the "crachin" in winter, but the cloud layer accompanying this phenomena is thin and the air is generally clear and dry above 6,000 feet.

In summer the situation reverses. Soil becomes untrafficable. The roads are almost useless when pounded by rain and rutted by vehicular traffic. Since even the hard-surfaced roads follow the river valleys in most cases, traffic on these main highways is often halted by bridge washouts and flash floods. Streams swell very rapidly following a summer thundershower, often rising from five to eight feet in a few hours. Mechanized forces are definitely at a disadvantage during this season.

Some air support can be rendered even in summer, if the techniques of extremely low-level flight are used. In most cases it is possible to fly under the cloud decks. The morning hours from seven till noon, when cloudiness is at a minimum for the season, offer occasional opportunity for conducting other types of air support operations.

Nevertheless, the summer season offers little hope for large-scale, modern warfare. While small ground parties traveling on foot can be utilized, a major operation by a mechanized force would be difficult, if not impossible, to support.

Thus, with all of man's ingenuity and technical knowledge, his actions must once again be subject to a greater power. The natural processes of nature still reign supreme.



AREAL OCCURRENCE OF TYPHOONS

ROCHESTER AMS MEETING

The 130th National Meeting of the AMS will take place at Rochester, N. Y. on 24–25 August 1954. The program has been arranged by the local chapter of the AMS and will feature the theme of agricultural and industrial meteorology. Meetings will be at the Chamber of Commerce. A dinner is scheduled for 24 August. Trips are planned to Eastman Kodak and Taylor Instrument Co.

Weatherwatch

The Vagaries of Spring 1954

DAVID M. LUDLUM, *Editor*

MARCH lived up to its reputation for weather vagaries in lion-like fashion with an abrupt change from the pattern that had dominated the nation's weather for five previous weeks. When the February temperatures were compiled, it turned out to be the warmest February for the country as a whole in the last 61 years, the period of systematic, nation-wide weather records.

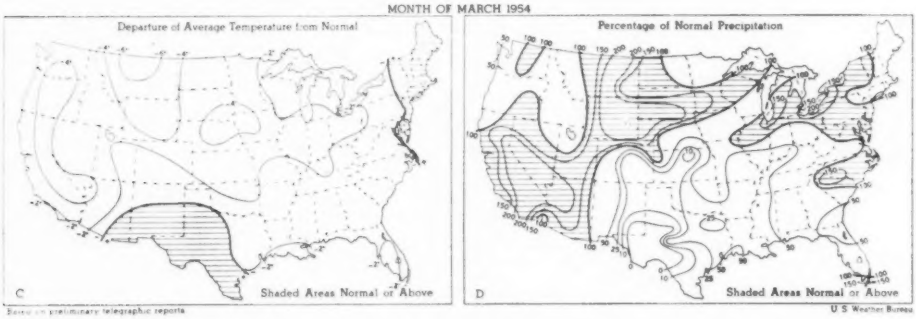
Circulation breaks of this type are more frequent between March and April, as has been pointed out recently by Jerome Namias; but March 1954 witnessed a return, after a five-weeks hiatus, to a winter type circulation, such as had existed in the extremely cold period during the middle days of January. In fact, at many northern localities March was a colder month than February, a very unusual occurrence. Harry Hawkins has brought out an interesting fact in the *Monthly Weather Review* that March 1954 continued a trend of the past eight years toward below normal temperatures in March. From 1948 to 1954, with the single exception of 1953, the transition month from winter to spring has experienced below normal temperatures, and in nine of the last 12 years the same trend has held true. There have also been some record-breaking cold months in recent autumn months. It is interesting to speculate on the effect of a small shift in phase of this apparent circulation periodicity with cold periods then occurring in winter and summer.

The dominant feature of the circulation in March was the institution of a weaker-than-normal westerly flow across the North American continent, to replace the fast westerly flow which had dominated during the mild mid-winter period. The March pressure distribution favored a northwesterly flow and encouraged a series of outbreaks of cold polar air into the United States, reaching all parts of the country consistently with the exceptions of the Rio Grande Valley and the Northeast.

The main feature of the mean upper-air charts was the development of a strong high pressure ridge over the western Gulf of Alaska and the Bering Sea to form an effective block to the Pacific westerlies. The air flow across the Pacific was effectively split into what meteorologists call a confluent jet stream. The westerlies divided in the western Pacific—one band circled the blocking high and swept down over Alaska and Canada as a cold air stream, while a southern band dipped under the blocking ridge and entered the continent at middle latitudes as a moist and relatively warm air stream. The meeting of these over the United States gave the month a very stormy character.

The monthly mean pressure distribution over the United States presented a deeper than normal trough just off the Pacific coast, part of the Aleutian low system which was pushed southeast of normal by the dominant Alaskan high. Over the Plateau there was a minor ridge with an extension northwestward along the Rockies to Alaska to provide a channel for the arctic air masses to rush southward. Over Eastern sections there was a large trough extending from Labrador south-southwestward to the eastern Gulf of Mexico.

March was a stormy month. Temperature con-



Departure of Mean Temperature from Normal in degrees Fahrenheit. USWB chart.

Percentage of Normal Precipitation. USWB chart.

trasts from south to north were greater than normal, and periodically the contrast between western and eastern sections was very great—a situation which makes for great cyclonic activity. Since a series of major storms moved across the country in an almost cyclical succession, perhaps it will be best to consider the weather events of March in terms of these cyclones.

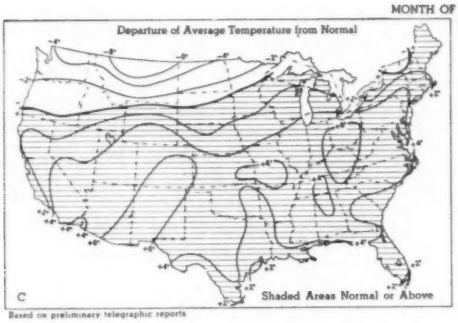
STORM NO. 1—As the month opened a series of north-south troughs were moving eastward across the central part of the nation, and heavy snow was falling in the Great Lakes region and the Ohio Valley northeastward. At Cleveland the passage of two troughs and the attendant northwest flow off the lakes produced five consecutive days of snowfall for a total of 20.8 inches—the greatest late-season storm total on record. Chicago, too, was strategically located in relation to the low centers and the lakes and received 12 inches of snow on 2 March, its biggest March snowstorm. The greatest traffic jam of the winter resulted throughout the area.

The most unusual snow occurrence of a widely snowy month took place in the Deep South. The southern end of the above-mentioned troughs lingered in the warm waters of the Gulf of Mexico, and a small wave formed on the front during 5 March. Rain, which had begun along the Gulf Coast of Alabama and Florida, changed to snow early on the 6th as a high, poised over Texas, fed cold air into the system. The result was the heaviest snowstorm of record at some stations and the greatest total since February 1899 at others. As reported by R. L. Anderson of Jacksonville, a four-inch fall was measured at Milton Experiment Station in extreme northwest Florida at 217 feet above sea level, and three inches fell at Niceville nearby. These are the deepest snows on record in Florida. These two stations were not in existence during the famous February 1899 snow and freeze when Pensacola reported a maximum fall of 2.1 inches, the same amount as reported there in the 1954 snow. Snow also fell in Alabama: Brewton 2.2 and Mobile 1.6 inches. Flurries filled the air as far south as Panama City, Live Oak, and Jacksonville Airport.

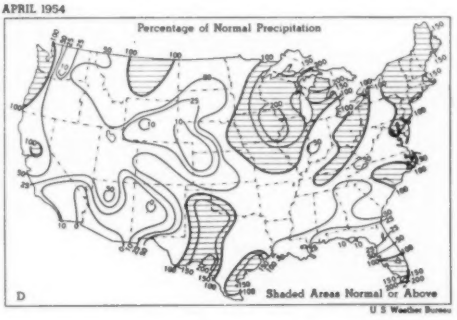
Frost and freezing temperature visited Florida's agricultural areas on the 2nd, 5th, and 8th and also in northern sections on the 7th. Considerable damage to unprotected tender crops and to some hardier plants resulted in exposed localities.

STORM NO. 2—March usually produces a noteworthy storm. In both 1952 and 1953 such major news makers occurred on 21 March. This month's outstanding storm appeared on the Pacific Coast on the 9th and finally passed to the east of Cape Cod on the 14th after producing a grand variety of weather phenomena. The cyclone reached its greatest development on the 11th and 12th when the center was slowly crossing eastern Colorado and Kansas with central pressures about 29.05 inches. High winds swept the central and southern Plains and whipped the dry, loose topsoil into severe dust storms, reducing visibility at times to almost zero and further damaging the grain crops and attempts at soil preservation. Blizzard conditions prevailed in Wyoming, South Dakota, and parts of Nebraska on the 12th, and further south a band of severe ice and glaze produced disruption of communication lines from Nebraska to Minnesota and Iowa. As the storm moved eastward across the Great Lakes and New England, heavy snow fell to the north (Massena, N. Y., 10″) and heavy rains and thunderstorms occurred to the south (Charlotte, N. C., 3.34″ on 13th). The sweep of the cold air behind the disturbance was marked: the maximum temperature at Springfield, Mo., on the 12th was 75° and on the 13th only 35°. The cold air touched off the season's worst series of tornadoes on the 13th in the Columbus-Macon area of Georgia. Eight persons were reported killed and $25 million damage resulted from these twisters as they whipped through the residential areas of two populous cities. Very cold weather for so late in the season reached to the Mexican border and the Gulf. Freezes occurred in Arizona and eastward through the fruit growing districts of Texas to Louisiana. The 32° mark at Jackson, Mississippi, on the morning of the 14th was a late season low mark.

STORM NO. 3—Another Pacific low entered the coast just as No. 2 was passing into the Atlantic. On the 15th a cyclone crossed the Oregon coast and dipped southward to Nevada and then eastward, following the general track of its predecessor, but moved slightly further to the north in its traverse of the central and eastern parts of the


MONTH OF APRIL 1954
Departure of Average Temperature from Normal
C
Shaded Areas Normal or Above
Based on preliminary telegraphic reports

Departure of Mean Temperature from Normal in degrees Fahrenheit. USWB chart.



Percentage of Normal Precipitation. USWB chart.

country. The lowest pressure was about 29.15 inches in Nebraska on the 18th. It again produced severe dust in the southern Plains, violent thunderstorms in the Ohio Valley and Pennsylvania, and heavy snow in northern New England. But the extreme cold air that had made Storm No. 2 so outstanding was lacking.

STORM NO. 4—The deepest barometric depression of the month developed in the same trough off the Pacific Coast which produced the other March weather-makers. It followed the usual course eastward over the central Plateau to northern Kansas, but there it began to deepen rapidly in a long polar trough aloft. Cold air fed southward behind the center and there was plenty of warm tropical air to the eastward—the result was a very deep depression that moved north-northeastward, along the usual track of a Plains storm, rather than along the east-northeast track followed by other March 1954 storms. With a closed circulation aloft around the whirl, the center reached the Lake Superior area with a central pressure below 29.00 inches. Further development took place in western Ontario as the center passed northeastward into central Quebec. High winds with speeds up to 70 mph were clocked across Michigan and Wisconsin on the 25th with considerable minor wind damage reported. The cold air drawn southward by this great whirl helped to produce the meteorological events of the 28–30th.

STORM NO. 5—Though this was not a cyclone in the classical sense, the weather events produced by the last disturbance of the month and the subsequent behavior of the following cold air mass makes an interesting study. Extremely cold air aloft for the season appeared over Canada on the 26–27th with temperature at 10,000 feet down to $-30°$ C. A surface anticyclone of great strength appeared over the Yukon on the 27th, while to the south along the slope of the Rockies a complicated frontal system formed along the boundary line between air of arctic origin and that of Pacific origin. The energy of this great cold air mass shunted the front further southward into the central Plains, and minor waves formed along the front to cause a broad zone of precipitation across the northern tier of states. Snow fell on the 28–30th in a band from the Rockies to the Atlantic. Sioux Falls, S. D., had 8″ of new snow on the 30th, while in the Northeast many stations reported their maximum late-season falls of record: Rochester, N. Y., 16″, Buffalo 14″, and Boonville, N. Y., 17″. Up to 24″ of snow fell in central Maine on the 29–30th.

APRIL'S CIRCULATION—The weather map for April underwent considerable change from the March pattern. Though the same features were present, they had made significant changes in position so that an entirely different flow pattern prevailed across the United States. After the first five days of April, the northwesterly flow, which had been the dominant feature of March, was replaced in the United States by a fast westerly flow from Pacific to Atlantic. Outbreaks of polar air, which had flowed southward so freely in March, were now confined to the region of Canada, so powerful was the westerly flow across the midcontinent, and thus reversed the thermal regime of the United States. Instead of below normal temperature readings, warm weather was the rule, the month averaging considerably above normal in all sections except along the northern border from the Pacific to Lake Superior and in the extreme Northeast. To the daily map reader, the main feature of the last three weeks of April was a west-east front across the northern Plains and the Lake region which separated the flow of Pacific air across central and southern United States from the polar air masses which were largely confined to Canada during this period.

The main development of the upper-air maps was the strengthening and westward movement of two high pressure areas. The Alaskan blocking ridge was stronger, but further west than in March, now being over the Bering Sea between Alaska and Siberia. With pressure much above normal over the area, there was a weak gradient southward to the Hawaiian Islands and generally weak westerlies across the mid-Pacific. The Aleutian low was displaced eastward, appearing as a trough extension of a large polar low, and cyclonic activity was more active over land areas than over the sea.

The Bermuda high entered the scene early in April and made an important contribution to the meteorological picture, particularly in the southwestern drought situation. The student of weather maps knows the close connection between the barometric configuration over the ocean near Bermuda and the characteristics of summer weather over eastern United States. By early April the Bermuda high had already assumed midsummer proportions and extended an arm over the Southeast and Gulf states. Thus the isobars over Texas assumed an alignment around the periphery of the Bermuda high which for the first time since last fall permitted moist Gulf air to flow northwestward to the parched plains.

The main cyclonic vortex over North America centered in the northern Labrador-Hudson Strait area, but the Bermuda high had squeezed out any resemblance of an eastern trough, so the temperature contrast was mainly between a cold Canada and a warm United States. Air flow was zonal across the lines of latitude.

APRIL'S ADVENT—Despite the month's being a notably warm one, the first week of April brought some remarkable temperature depressions in the Northeastern states. On the 5th the lowest April reading ever reported in the New England states occurred at First Connecticut Lake, New Hampshire, elevation 1660 feet, astride the Canadian border. The mercury dipped to a $-17°$ reading after a night of intense radiation. This was ten degrees lower than any previous April reading in New England, according to James McGuire of the Boston USWB. The lowest in nearby New York State was $-10°$ at Saranac Lake on 4 April. This did not equal the all time April mark of $-24°$ established in 1923. It is interesting to note that the lowest reading at Burlington, Vermont, situated midway between these record readings, was only $+11°$ on the same morning. The cold air mass passed off the coast on the 6th, and there followed on the 7th in the Northeast the first day since late February that bore any resemblance to spring conditions.

THE RAINS COME—By far the most important recent meteorological and economic event was the beginning of the alleviation of the fall-winter-spring drought in the southern and central Plains.

March had been the second driest in Texas history and followed a very dry January and February, giving the three-month period only 35 per cent of the normal precipitation. The winter wheat crop would have been a complete loss, no spring crops could have been planted, and range lands would be bare another year—unless the rains came.

After another week of rainless skies, the circulation pattern shift across the continent made itself felt and April showers began to fall at scattered points over the southern portions of the incipient Dust Bowl. On 8 April Gulf air commenced to flow up the Rio Grande Valley, and showers broke out; Del Rio, which had been practically rainless for six months, received .86″ in one day. The Gulf air worked further northward and northwestward during the next four days, bringing falls of over an inch in Texas and up to two inches in Oklahoma. Further rains fell on the 14–15th, but then ensued another rainless period until the 21st when intermittent showers again fell over a wide area. The April rains broke the drought, at least temporarily, in the southern and eastern sections of the area and eased the situation somewhat in southwestern Nebraska, western Kansas, and eastern Colorado and New Mexico. There was a distinct improvement in the condition of wheat, but the crop at the end of April was still in "mostly fair to poor condition" with continued growth dependent on further rains.

That farming marginal climatic regions is a hazardous occupation was emphasized by an onslaught of another weather element—frost. The cold weather that overspread the Plains on the first of May resulted in a freeze on higher elevations in western Texas and Kansas with considerable damage to the wheat crop. But crop prospects definitely took an upturn with the commencement of a four-day soaking rain on the 11th, such as the southern Plains had not seen in four years. A low pressure system with a definite cyclonic circulation aloft moved eastward from California to the northern Gulf of Mexico during the 11–15th, and all of the Dust Bowl area benefited. In Texas rains up to six inches were welcomed as Gulf air was brought into the circulation to set off a series of widespread showers. The crops which had survived the drought and the freeze were now assured of a harvest, but farmers were now complaining that some of their fields were too wet to work for new plantings and that the growth of weeds threatened other crops!

High Schools

The October issue of *Weatherwise* will be devoted to meteorology in secondary schools. The editors would welcome receiving from teachers brief accounts of how weather work is coordinated into their science program so that representative accounts may be included in the issue and serve as guides to prospective teachers. Pictures of student activity will also be very welcome. Kindly forward material by August 1st.

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Weather Modification. K. M. Arenberg, F. G. Bemis, C. A. Cushman, E. Neisser, G. P. Thomas, and D. H. Vetterlein. Weymouth Press for Weather Modification Group, 270 Beach St., Wollaston, Mass. 100 p., illustrated. $3.00.

This brief survey of the entire subject of weather modification should be welcomed by the meteorological profession and the general public as well. It brings together in short compass the main facts and opinions concerning this controversial subject which have hitherto been scattered throughout a multitude of publications and sources.

The authors have written from the point of view of the conservationist with emphasis on our current and future needs for that vital commodity—water. They are in an enviable position to make this impartial survey since they are detached from the controversies which have raged in the profession and have been able to put many of the subjects and actors in the weather-making drama in their true perspectives. The work was originally submitted by the authors in partial fulfillment of a course in manufacturing at the Harvard Graduate School of Business Administration.

Perhaps the best way to outline the contents will be a listing of chapter headings: Historical background of rainmaking, Cloud physics, Methods of evaluation, Government activities, Regulation, Potential applications, and Conclusions. There is an appendix containing a chronological list of the history of rainmaking, footnote references, a bibliography, and acknowledgments.

Though stating that weather modification is "still in its embryo stage of development," the authors state that "there is little doubt that the seeding of clouds under the proper conditions will induce precipitation in greater quantities than would have occurred naturally." They believe that precipitation can be increased by an amount that is "statistically significant."

Their chief recommendation looks forward to the establishment of a small coordinating office in Washington to act as an information center and an advisory group. They in no way suggest federal regulation, but would like to see the public lands used as an area for testing all types of rainmaking experiments. The authors view rainmaking as only one way in which available water may be increased. They plea for funds now since "the importance of weather modification for the future cannot be overemphasized."

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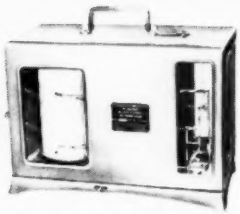

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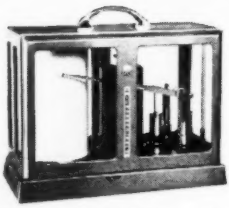

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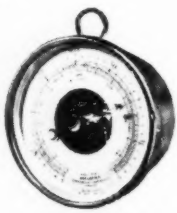

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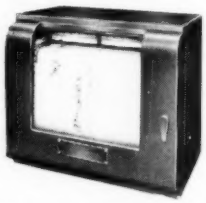

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